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不同海拔地区种植的水稻地上部干物质生产和分配对氮素底肥的反应

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摘要 1983——1985年在云南省的元江（海拔约400米）、昆明（约1900米）和丽江（约2400米）作了水稻的不同剂量（每亩30公斤、20公斤和零公斤尿素）的氮素底肥试验。比较了各地之间和不同底肥处理之间在不同生育期中水稻地上部干物质的生产和分配。并对所获得结果的生理基础和气候条件的作用进行了讨论。

关键词 水稻；干物质生产；干物质分配；次库；底肥；氮素肥料

虽然水稻对氮肥的反应有过极广泛的研究，但在田间条件下对不同海拔地区种植的水稻对氮肥的反应却并未见过系统的研究，这方面工作开展的不多，当然有各种原因，但主要可能是在大多数稻区并未碰到在海拔相差很大的地区种植水稻的生产实践的要求。这在云南却是现实的问题，因为云南的水稻栽培由几百公尺海拔一直到二千多公尺，在这样大的高差上各地的光、温、气压和气体成分以及风速等等都不相同[1]。水稻的品种、种植技术和产量也很不相同，因此云南省科委组织了“高原水稻高产栽培的生理生态规律研究”。在其中我们于不同海拔的稻区布置了不同氮素底肥的试验，试图通过对地上部分干物质生产和分配的分析，了解各地对氮素底肥的反应，为不同海拔地区种植水稻的施肥措施提供一些参考。

环境、材料和方法

试验地的环境条件已在另文叙述[2]，所用品种元江、昆明均为滇榆一号，丽江为黑选五号，每小区面积一分，隔埂包以塑料薄膜以防渗漏。不施肥为对照，20公斤/亩尿素作底肥为中剂量，30公斤/亩尿素作底肥者为大剂量，均不施有机肥，重复三次。不同生育期采样，分器官烘干称重以及所有其它分析、测量的方法均与以前相同[2]。

结 果 和 讨 论

在图1中分别画出了元江、昆明和丽江种植的水稻中干物质累积随播种后的时间推移的变化。

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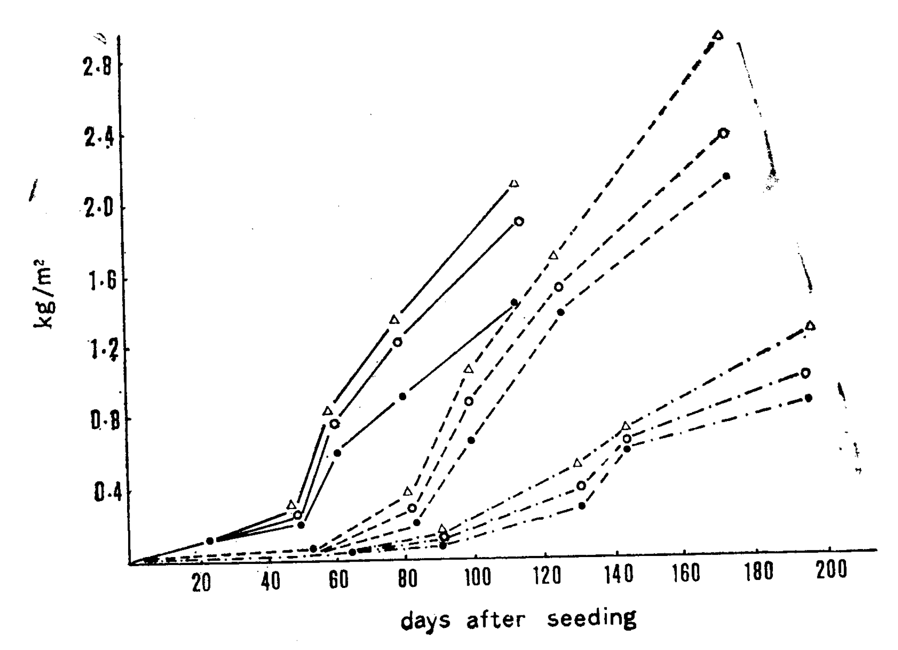


图 1 不同海拔地区种植的水稻在不同氮素底肥下地上部干物质的累积随时间的变化

—— 元江；……昆明；—·—·— 丽江。△ 大剂量；○ 中剂量；· 对照

Fig. 1 Changes in dry-matter accumulation in the aerial part of rice grown at different altitude localities under conditions of different basal dressing with nitrogenous fertilizer as time goes on.

—— Yuanjiang; …… Kunming; —·—·— Lijiang; △ Large dose; ○ Middle dose; · CK

由图 1 可以看出各地均以大剂量氮素底肥生产最多的干物质。但三地相比，以温凉的昆明地区的最高，这主要是由于低热的元江生长期过短；冷凉的丽江其光合作用速率过低所致[3]。不过就干物质生产速率（克·米$^{-2}$·天$^{-1}$）而论，则元江最高，昆明次之，丽江最低，亦即随海拔增高干物质生产速率依次降低。

地上部总干物质生产对氮素底肥的反应各地有所不同。从图 1 可以看出，低海拔地区种植的水稻，两种施肥处理之间的差异并不大，但都明显地高于对照；而高海拔地区的水稻则是中剂量的稍高于对照（两者较接近），却都明显地低于大剂量。就其随时间前进的变化来看，三种处理之间的差异也因海拔不同而异。低海拔地区种植的水稻，三种处理之间的差异一直在扩大，直到黄熟。而高海拔冷凉地区丽江的水稻，在抽穗前后，三种处理的干物重有趋同的倾向。抽穗后又渐次扩大。呈现前后期差异大，而中期差异小的特征。海拔居中的昆明地区种植的水稻，其差异则处在二者之间。

造成对氮素底肥反应的上述差异的原因，可能主要是由于不同海拔地区水稻生长期中温度变化不同，引起各生育期土壤供肥能力不同的影响；高海拔地区在水稻生长的前期和后期温度较低，土壤本身的供肥能力较差[4]，因而施用氮素肥料明显地增加了干物质生产。中期温度较高，改善了土壤供肥能力，相比之下对照比两种施肥得益更大，使其干物质生产更接近于施肥处理。在低海拔地区，水稻本田期温度并未成为土壤供肥

能力的限制，或者说土壤供肥能力在整个本田期都较为一致，氮素底肥对干物质生产的影响受土壤肥力干扰较小，因而三组处理之间的差异维持始终。

至于高海拔地区的水稻，中剂量处理的干物重在抽穗后更接近对照，而低海拔地区的更接近大剂量处理，进一步反映出高海拔地区种植的水稻在抽穗后比低海拔地区的更需氮肥。从表 1 可以看出，高海拔地区种植的水稻比低海拔地区的，不但齐穗后的干物质生产率增加更多，而且齐穗后生产的干物质量占全生育期总量的比例也较高。而在此期中，高海拔地区的水稻又碰上温度下降引起的土壤供肥能力下降，较高的干物质生产要求更多的氮素支持，但供应却减少了，这可能造成在高海拔地区即使给水稻中剂量氮素化肥，它也仍感到氮不足。与大剂量相比，中剂量的最终总干物质量就明显地低，而比对照高出不多。

抽穗后不同地区种植的水稻，在不同处理间的差异主要表现在干物质的分配和再分配上。图 2 表示的是三地种植的水稻在不同氮素底肥下次库（茎＋叶鞘）干物质累积的时间进程。可以看出，最大的差异出现在齐穗期至黄熟期之间，这正是籽粒充实的关键时期。事实上在不同海拔地区的水稻上，由于施用氮素底肥都相对增加了次库的干重。造成这种情况的原因，主要是施氮增加了旗叶后期的光合作用速率[3]。只不过是在低海拔地区的水稻中，较强的光合产物流抑制了齐穗前次库贮备的干物质向籽粒运输[2]，而高海拔地区的水稻则是此期的光合产物有一部分继续在次库中积累。

施用氮素底肥相对增加了黄熟期次库干重的另一个原因，是和氮肥增加水稻叶面积有关。由表 2 可以看出，氮素底肥对叶面积指数的影响比对每平方米（土地）粒数的影响更大。这造成了库／源比（每平方米叶子供应的籽粒数）较大的差异。由于施用氮素底肥减低了库/源比值，就有了较强大的源，与对照相比，光合产物就有了较多的余裕，其次库相对增重就很自然了。最终影响了穗增重对总增重之比和结实率。

表 1　不同海拔地区氮素底肥对水稻干物质生产率（克·米$^{-2}$·天$^{-1}$）和齐穗期干重占全生育期总干重%的影响

Table 1　Effects the basal dressing with nitrogenous fertilizer on dry-matter production rate (g·m^{-2}·day^{-1}) and dry weight produced after the full heading time making up the percentages of total dry weight of rice grown at different altitude localities during the whole growth period duration

		元江 Yuanjiang			昆明 Kunming			丽江 Lijiang		
		CK	M	L	CK	M	L	CK	M	L
干物质生产率（克·米$^{-2}$·天$^{-1}$） Dry-matter production rate (g·m^{-2}·day^{-1})	抽穗前* before heading*	12.7	15.5	17.3	11.2	12.3	13.5	2.7	3.6	4.8
	抽穗后** after heading**	13.9	16.6	22.1	15.9	17.8	26.4	4.3	7.1	11.1
齐穗后增加的干重占全生育期总干重（%） Dry weight produced after full heading time making up total dry weight during the whole growth period duration (%)		27.6	27.8	37.2	35.4	34.0	37.9	36.9	36.7	42.9

*　抽穗前：播种至齐穗。　**　抽穗后：齐穗至黄熟。　CK，M和L分别表示对照，中剂量和大剂量。

*　Before heading, from seeding to full heading.　**　After heading, from full heading to yellow maturity.　CK, M and L denote check, middle and large dose, respectively.

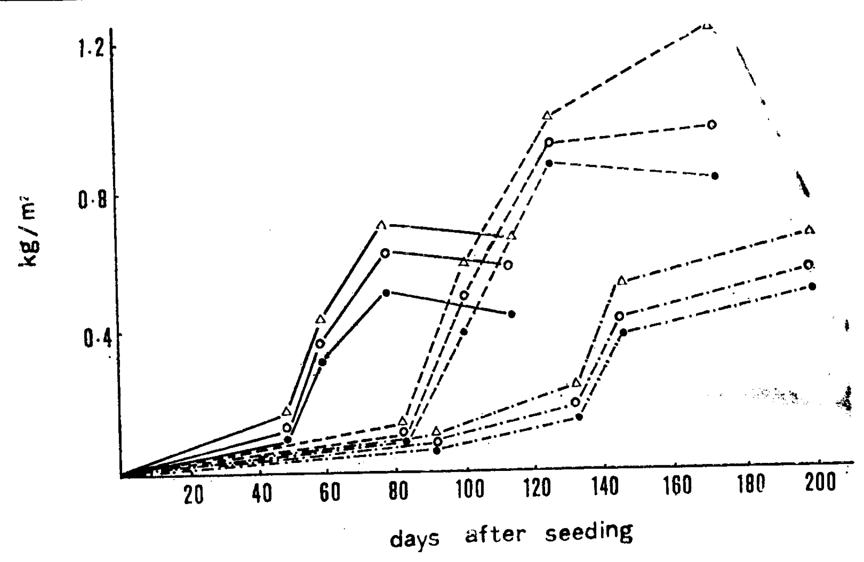


图 2 在不同氮素底肥下次库（茎+叶鞘）干物质累积的时间进程

—— 元江；…… 昆明；—•—• 丽江；△ 大剂量；○ 中剂量；• 对照

Fig. 2 Time course of dry-matter accumulation of secondary sink (stem+leaf sheath) under conditions of different basal dressing with nitrogenous fertilizer.

—— Yuanjiang; …… Kunming; —•—•— Lijiang; △ Large dose; ○ Middle dose; • CK

表 2 氮素底肥对叶面积、库容量、库/源比和穗增重/总增重比、结实率的影响

Table 2 Effects of basal dressing with nitrogenous fertilizer on leaf area, sink size, sink/source ratio, increase in ear weight/increase in total weight ratio and seed setting percentage

	元江 Yuanjiang			昆明 Kunming			丽江 Lijiang		
	CK	M	L	CK	M	L	CK	M	L
叶面积指数 Leaf area index	4.50	7.83	9.17	6.62	7.92	10.40	2.55	3.74	5.70
粒数/米²地面积 Number of grains/m² cultivated area	34214	46931	46606	41267	47653	49399	21766	28232	36750
粒数/米²叶面积 Number of grains/m² leaf area	7603	6065	5303	6133	6016	4097	8535	7630	6447
穗增重/总增重（%） Increase in ear weight/increase in total weight (%)	123.3	110.0	109.1	106.2	91.3	80.7	81.4	77.6	70.2
结实率（%） Seed setting percentage (%)	91.2	89.0	80.8	73.4	74.4	64.4	57.2	67.2	48.7

CK，M和L分别表示对照，中剂量和大剂量

CK, M and L denote check, middle and large dose, respectively.

从上述结果来看，增施氮素底肥对提高源的强度，特别是后期的源强度，的确有好的作用。但大量的底肥处理会过多地减小库/源比例，浪费了源的能力，并不可取。但在高海拔地区，中等剂量的处理却仍存在源不足，为得到较好的后期干物质生产和分配，仍有必要进一步研究。

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RESPONSES OF DRY-MATTER PRODUCTION AND PARTITIONING IN THE AERIAL PART OF RICE GROWN AT DIFFERENT ALTITUDE LOCALITIES TO BASAL DRESSING WITH NITROGENOUS FERTILIZER

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Abstract From 1983 to 1985, authors had made the field plot experiments on different doses of basal dressing with nitrogenous fertilizer (urea) of rice (*Oryza sativa* L.) in Yuanjiang (dry-heat river valley about 400 m altitude), Kunming (warm-cool plateau lake-shore about 1900 m altitude) and Lijiang (cold-cool plateau area about 2400 m altitude), Yunnan, respectively. The treatment of basal dressing was divided into three doses which the one was not applied with urea (CK), the other was applied with 20 kg/mu urea (middle dose) and the third was applied with 30 kg/mu urea (large dose). At the same time, each dose was replicated three times. The dry-matter production and partitioning in the aerial part had been made a comparison among the treatments of different doses. The main results are as follows:

1. The responses of total dry-matter production to basal dressing with nitrogenous fertilizer are that with the advance of the time, the differences among the treatments of rice grown at the low-altitude localities are continuously and constantly increased; while total dry-matter production of rice grown at the high-altitude localities exhibited convergent tendency around heading period, and that at the yellow ripe stage the differences among the treatments are increased once more.

2. All the treatments of large dose of rice grown at various localities produced

the most dry-matter. Differences between the treatments of two doses at the high-altitude localities are larger than those at the low-altitude localities, that is, at the low-altitude localities the differences in the dry-matter production between the treatments of middle and large dose are lesser as compared with that of the CK, while at the high-altitude localities the dry-matter production of the treatments of middle dose is slightly higher than that of the CK and is markedly lower than that of the treatment of large dose.

3. All the applications of basal dressing with nitrogenous fertilizer increased dry-matter production after heading of rice grown at different altitude localities, and the dry-matter production increases as the dose increases, however, those at the high-altitude localities increase more markedly.

4. The effects of basal dressing with nitrogenous fertilizer on the weight of secondary sink (stem + leaf sheath) of rice from the heading to the yellow ripe stage are that the decrease in weight of secondary sink is hindered at the low-heat localities, while the increase in weight of secondary sink is increased at the high-altitude localities, and what is more, the larger the dose is, the more obvious ish the increase in weight, that is to say, all the applications of basal dressing wit nitrogenous fertilizer relatively increased the weight of secondary sink.

5. As regards the ratio of increase in ear weight to increase in total weight from full heading time to yellow ripe stage, the ratios of rice grown at different altitude localities are decreased by application of basal dressing with nitrogenous fertilizer, and that with the increase in dose the ratios are decreased more, but this ratio of rice grown at the high-altitude localities shows much more obviously than at the low-altitude localities.

6. All the seed setting percentages and grain-to-straw ratios of rice grown at different altitude localities are decreased through the application of basal dressing with nitrogenous fertilizer, but the seed setting percentage of rice grown at the high-altitude localities is increased with the application of middle dose (20 kg/mu urea).

The physiological basis and action of climatic condition in the results mentioned above had been discussed.

Key words Rice; Dry-matter production; Dry-matter partitioning; Secondary sink; Basal dressing; Nitrogenous fertilizer